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How Lean Product and Process Development Can Improve Your R&D Results

Lawrence J. Navarre
Kettering University, lnavarre@kettering.edu

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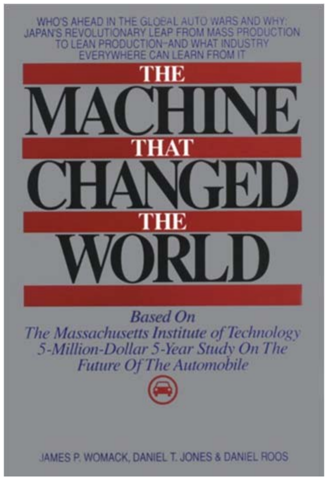
How Lean Product and Process Development Can Improve Your R&D Results

Larry Navarre, Lecturer

Department of Business, Kettering University

Lean Thinking to LPPD



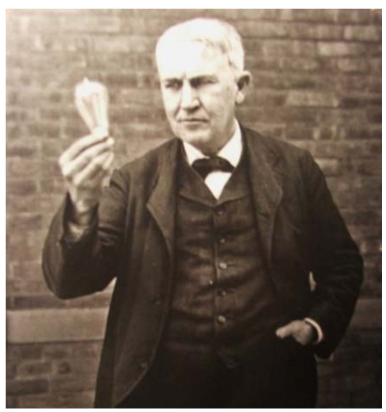
1990

Lean Production

Mass Production

Craft Production

"Edisonian" Inventors



Discovery

"Corporate" R&D

Controlled Process

Lean Development

Learning

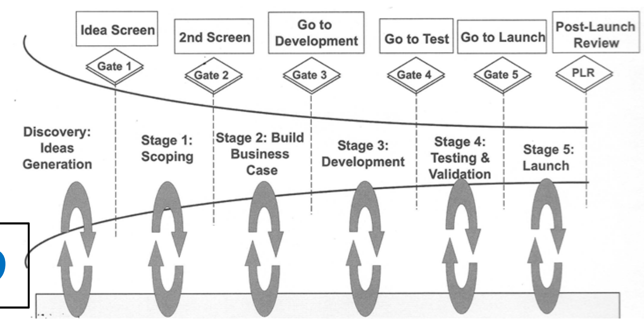
LPPD and Development Processes

Sequential

4 D's

Discover
Design
Develop
Deploy

Stage-Gate



Cooper, R.G., Winning at New Products, 2011

Lean PD

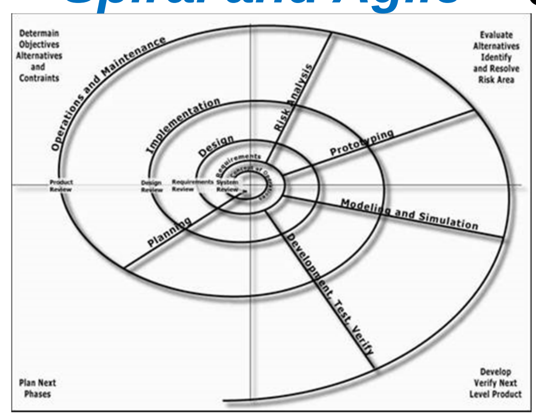
Unstructured

No Formal Process

Structured

Skunkworks

Spiral and Agile



Non-sequential

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LPPD Origin

- **Toyota Motor Corporation**
  - **Studies by University of Michigan faculty**
  - **Observed that, like Lean Manufacturing, Toyota was doing something dramatically different in product development**

LPPD Origin

- **1980's-1990's**
  - **Study of why Japanese car companies were successful led to only one company with a difference – Toyota**
  - **Toyota's development process performance:**
    - **30% faster using**
    - **50% fewer resources**
    - **Award winning products**
    - **Steady market share growth**
  - **In short, better cars faster and cheaper**

The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster; **Ward, Liker, Cristiano, Sobek; MIT Sloan Management Review, April 15, 1995**

LPPD Origin

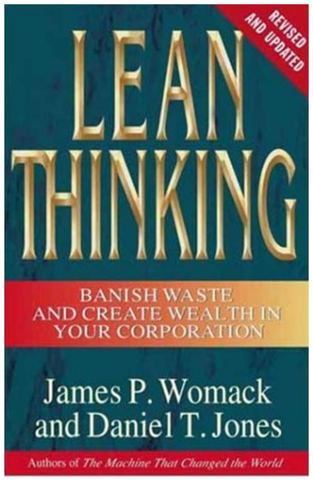
- **Lean Development is very "new" (circa 1995)**
  - **Original Documented Research**
    - ***The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster,*** **MIT Sloan Management Review, April 15, 1995; Ward, Liker, Cristiano, Sobek**
  - **Product Development for the Lean Enterprise**
    - **2003 by Michael Kennedy, NCMS, Ann Arbor, MI**
      - **Forward by Dr. Allen Ward**
    - **2008 revised as *Ready, Set, Dominate: Implementing Toyota's…***
      - **Forward by Dr. Durward Sobek**
  - **Lean Design Guidebook**
    - **2004 by Ronald Mascitelli, Technology Perspectives, Inc.**
    - **Revised in 2011 as Mastering Lean Product Development**
  - **The Toyota Product Development System**
    - **2006 by James Morgan and Jeffrey Liker**
  - **Lean Product and Process Development**
    - **2007/2014 by Allen Ward and Durward Sobek**

What is LPPD?

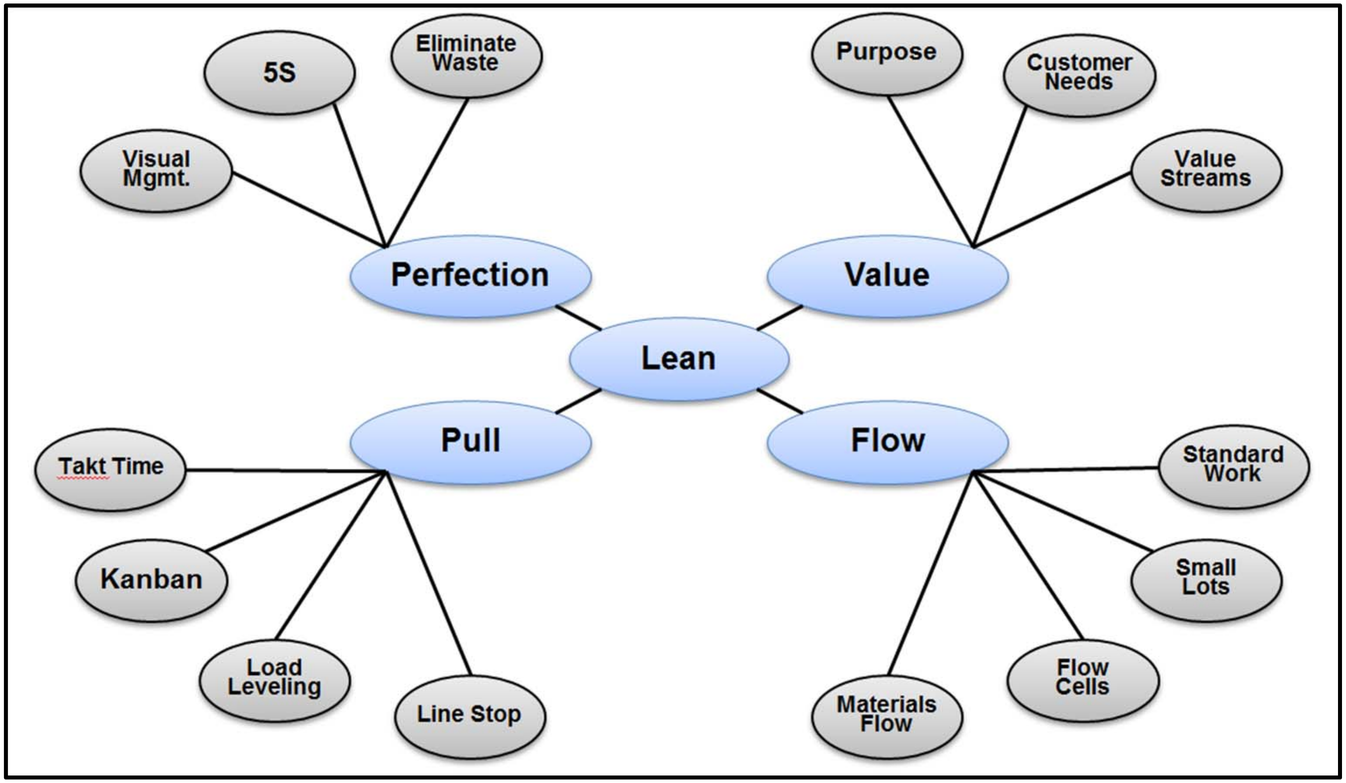
- **Lean Product and Process Development**
  - **The application of Lean principles to the business process of product and service development**
  - **LPPD is quite different from Lean Manufacturing**
  - **But the principles of Lean Enterprise are very relevant and applied appropriately**
  - **LPPD “translates” Lean to Product Development**

What is LPPD?

LPPD applies Lean Thinking to the process of development



1996



Navarre, L.; A Taxonomy of Lean Concepts Supporting Core Principles of Lean, *Lean Education Body of Knowledge, Chapter 4*, (pending 2016)

What is LPPD?

- **The Basic Secret**

  - **Traditional PD is about following formal process**
    - **Formal steps in a sequential order with regular management approvals**

  - **Lean Development is about Learning**
    - **Learning fast how to make good products**
    - **Success through the goal of knowledge-based, learning-based development**

Ward, Sobeck; *Lean Product and Process Development*, Lean Enterprise Institute, 2014

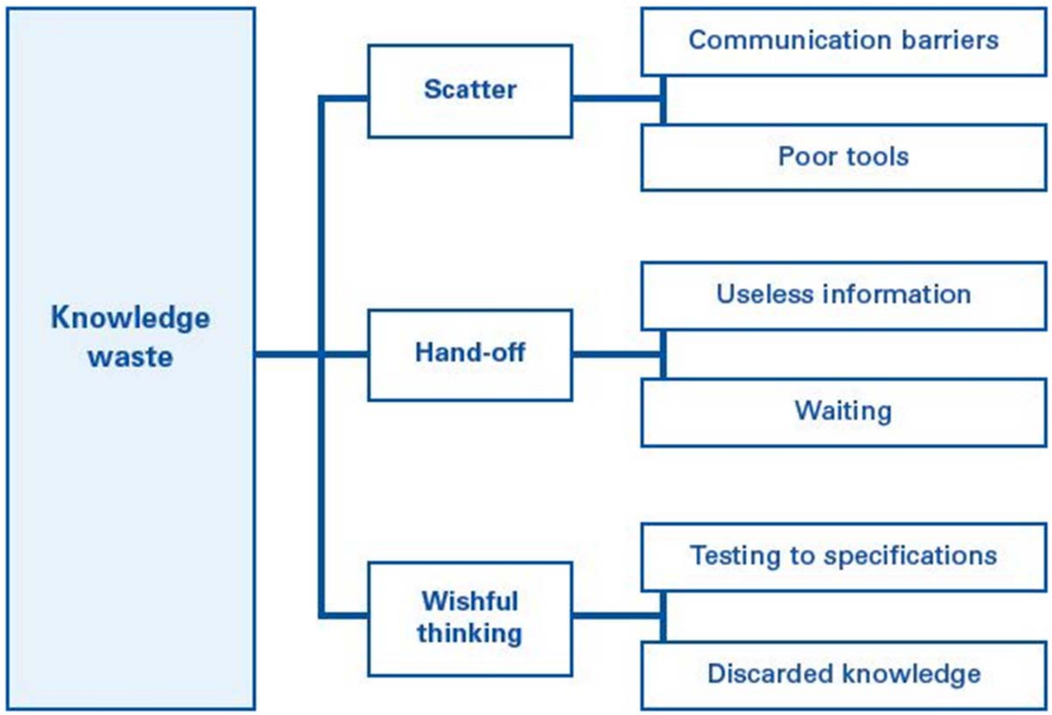
What is “Waste” in NPD?

- **Eliminating Waste**
  - At the core, Lean is eliminating waste
  - Every principle of Lean appears to be a countermeasure against waste

  - Let’s “translate” waste in Lean Enterprise to LPPD

What is “Waste” in NPD?

- **Since NPD is mainly information transfer, the source of waste in NPD is Knowledge Waste**



Ward, Sobeck; *Lean Product and Process Development*, Lean Enterprise Institute, 2014

What is “Waste” in NPD?

- **Communication Barriers**
  - Engineers are physically, socially separated from production
  - Lack methods to turn data into usable knowledge
- **Poor Tools**
  - Traditional product development has few Lean tools
  - LPPD has simple tools to reuse knowledge and schedule work
- **Useless Information**
  - Requiring useless information to “control the process”
  - Best engineers are doing admin, not engineering

Ward, Sobeck; *Lean Product and Process Development*, Lean Enterprise Institute, 2014

What is "Waste" in NPD?

- **Waiting**
  - Conventional project management scheduling causes the waste of waiting
  - Leave responsibility to schedule work to the people delivering the knowledge
- **Testing to Specifications**
  - Nothing is learned by validating the spec
  - The job of Testing is to break the product
- **Discarded Knowledge**
  - Most companies file it and forget it
  - Engineers must turn data into usable knowledge for future projects

Ward, Sobeck; *Lean Product and Process Development*, Lean Enterprise Institute, 2014

What is “Value” in NPD?

- **The output of NPD is Usable Knowledge**
  - **NPD is mainly the development of knowledge, or information**
  - **But customers don’t pay for knowledge**
  - **Customers pay for products and services, therefore…**

Ward, Sobeck; *Lean Product and Process Development*, Lean Enterprise Institute, 2014

What is "Value" in NPD?

- **Value in NPD is transferring Usable Knowledge into Operational Value Streams**
  - **An operational value stream is the part of the organization that delivers the product or service**
  - **Operations is the customer of Development**

Ward, Sobeck; *Lean Product and Process Development*, Lean Enterprise Institute, 2014

What is "Value" in NPD?

"Toyota had it easy… they handed off design to the best process development in the world"

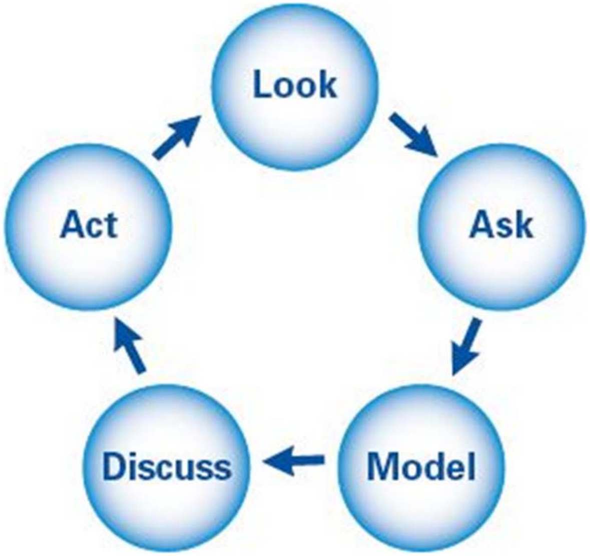
Jim Womack, PhD, Professor at MIT
Co-author of the Machine that Changed the World and Lean Thinking
Founder of Lean Enterprise Institute
Presenting at Lean Product and Process Development Exchange, 9/23/2014

Womack's Insights:

- **The Toyota production system is the creator of Lean Manufacturing, arguably the world's best manufacturer**
- **Most organizations don't have such a capable production capability, so "Creating Operational Value Streams" is an important part of development**

The Fundamental Value-Creating Cycle

- **LAMDA**
  - **Look – go see for yourself**
  - **Ask – get to the root cause**
  - **Model – use analysis, simulation, prototypes**
  - **Discuss – with peers, mentors, and developers of interfacing sub-systems**
  - **Act – test your understanding experimentally**



Then Look again! The difference of Lean PD is in focusing on knowledge value *"because problems almost always arise because of a gap between what we think we understand and reality"* – John Shook

Ward, Sobeck; *Lean Product and Process Development*, Lean Enterprise Institute, 2014

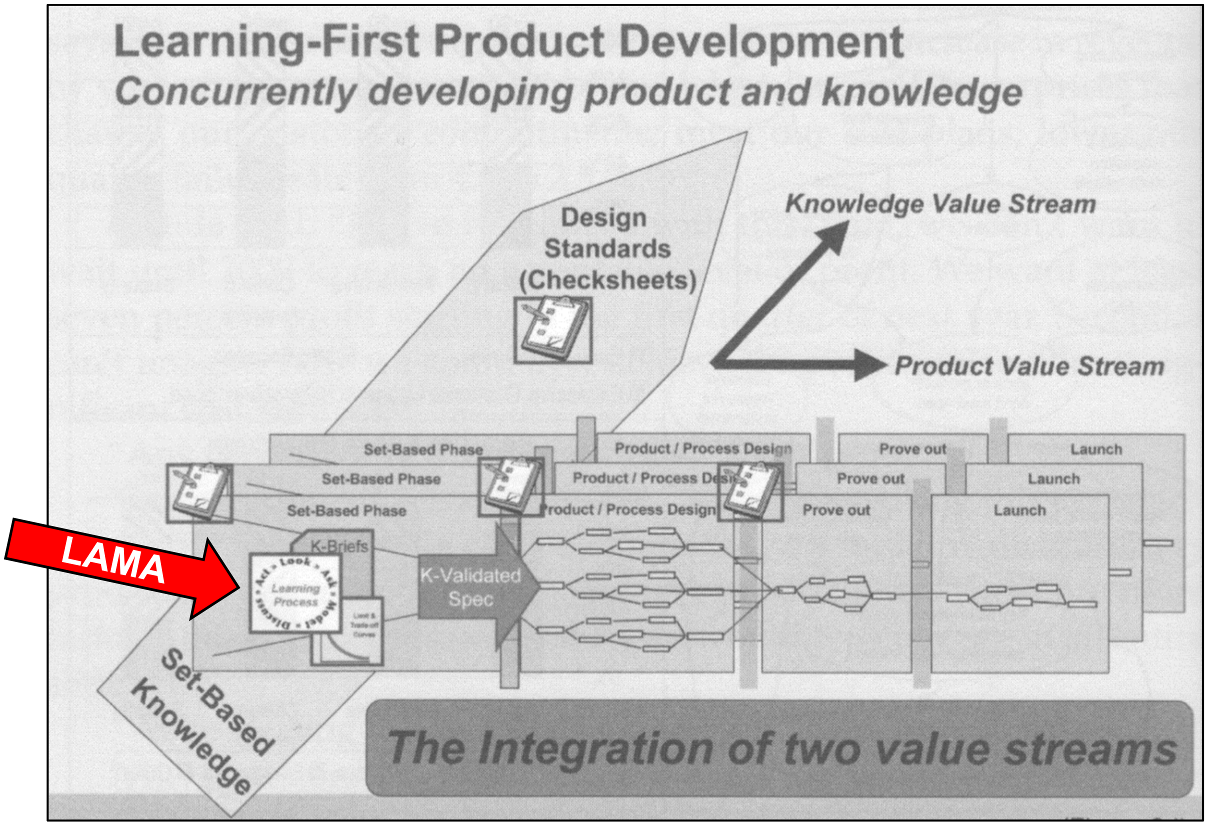
The Fundamental Value-Creating Cycle

- **LAMDA**
  - **Competitive advantage is derived from discovering new principles specific to your products, and obtainable only from your experience**
  - **The LAMDA cycle enables knowledge creation**
  - **Turning data into usable knowledge as stored in Trade-off Curves, Knowledge Briefs, and Design Checklists**

Ward, Sobeck; *Lean Product and Process Development*, Lean Enterprise Institute, 2014

The Fundamental Value-Creating Cycle

- **LAMDA generates learning which is recorded in Knowledge Briefs and formalized in Design Standard Checklists**



Ready, Set, Dominate – Implement Toyota's Set-Based Learning for Product Development; Michael Kennedy, Kent Harmon, Ed Minnock; 2008

The Fundamental Value-Creating Cycle

- Integration of Two Value Streams
  - Knowledge Value Stream
    - Turning data into usable knowledge as stored in Trade-off Curves, Knowledge Briefs, and Design Checklists
    - Reused from project to project, continuously improved over time
  - Product Value Stream
    - Using the Knowledge Value Stream as applied to each specific project
    - Adding more knowledge to the Knowledge Value Stream

The Four Cornerstones of LPPD

- **Entrepreneurial System Designer**
  - **A "heavyweight" project leader with strong market and product knowledge is accountable for project success**
- **Cadence, Flow, and Pull**
  - **Key principles of Lean Manufacturing applied to the management of NPD projects**
- **Teams of Responsible Experts**
  - **Functional representatives that develop deep expertise through learning and knowledge management**
- **Set-Based Concurrent Engineering (SBCE)**
  - **Many ideas are evaluated to gain knowledge of design trade-offs before commitment to the final design**

Ward, Sobeck; *Lean Product and Process Development*, Lean Enterprise Institute, 2014

a Pause to Stretch Before Exercise

Set-Based Concurrent Engineering

- **The "Second Paradox"**
  - **The first paradox was the dramatic difference of Lean Production from Mass Production**
  - **The second paradox was the dramatic difference in Toyota's development process from all other automakers**
  - **Although other aspects of the Toyota development process were logical, the process of SBCE appeared inefficient**

***The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster*; Ward, Liker, Cristiano, Sobek; MIT Sloan Management Review, April 15, 1995**

Set-Based Concurrent Engineering

The "apparent inefficiency" of SBCE

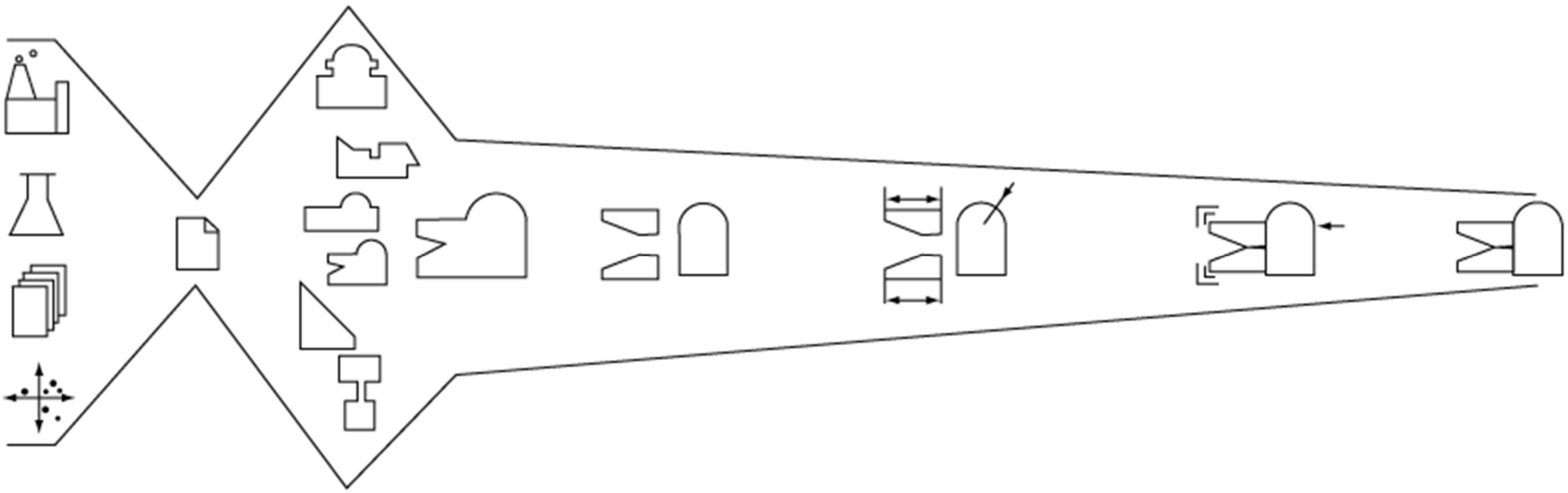
1. **Delay Design Decisions**
2. **Multiply Prototypes**
3. **Less Structured Process**

Normal Concurrent Engineering	Set-Based Concurrent Engineering
Seek to freeze specifications quickly	Delay design decisions and choose hard specifications late in the process
Reduce the prototypes needed due to concurrency	Multiply prototypes, to what appears an absurd degree
Highly structured, detailed project process	Less structured process focused on meeting milestones

***The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster*; Ward, Liker, Cristiano, Sobek; MIT Sloan Management Review, April 15, 1995**

The Traditional Design Process

- Rapidly converge to a concept, then test
  - A narrowing process of a wide range of product concepts to a reliably producible product
  - "Design-then-Test"



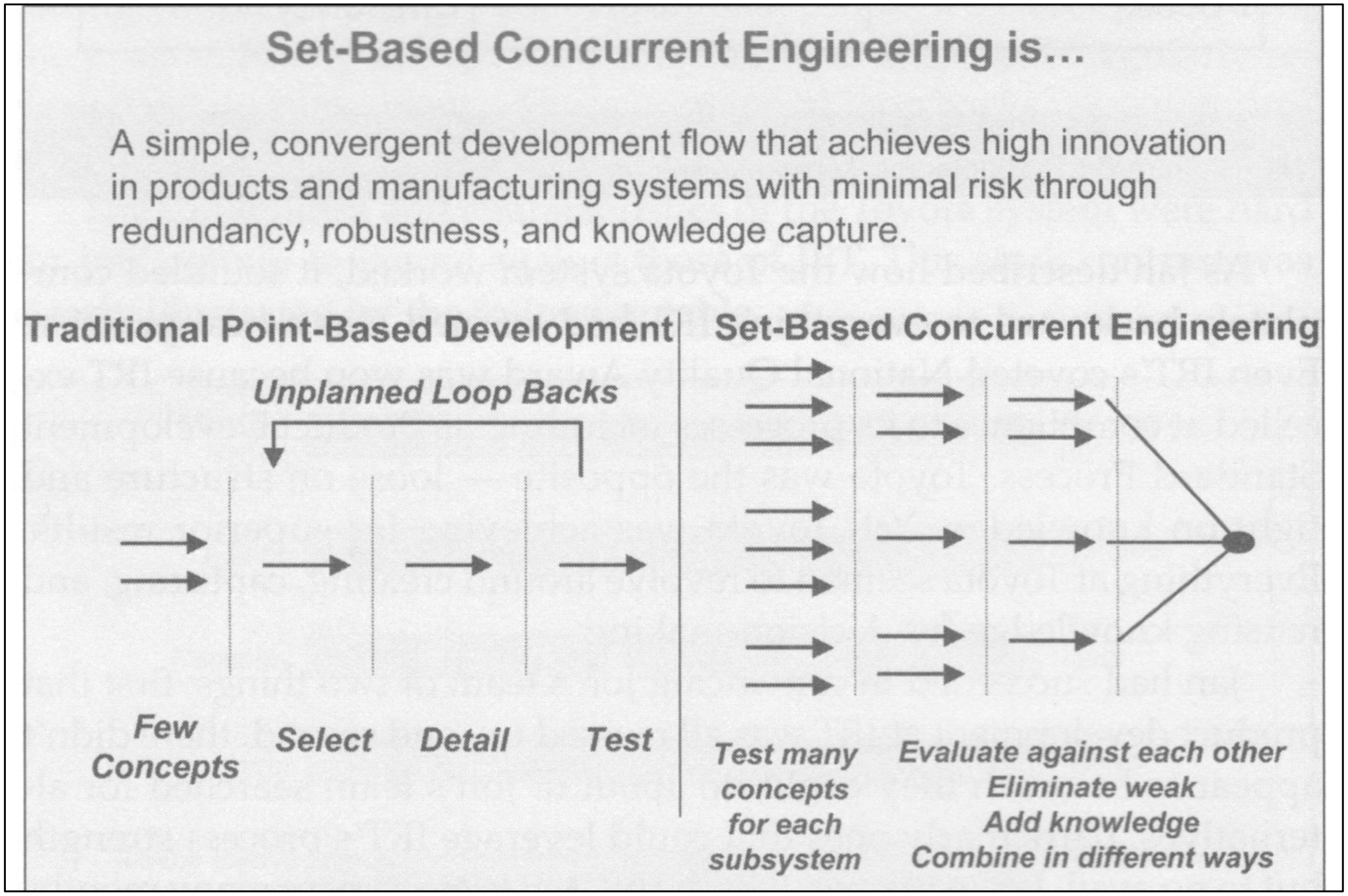
Ulrich/Eppinger, Product Design and Development, pp.13-14

Set-Based Concurrent Engineering

- **Exploring sets of solutions, then slowly converge to a concept**
  - **A learning process of extensive prototyping**
  - **“The manager’s job is to prevent people from making decisions too quickly”**
    - **Toyota GM of Body Engineering**
  - **“Test-then-Design”**

***The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster*; Ward, Liker, Cristiano, Sobek; MIT Sloan Management Review, April 15, 1995**

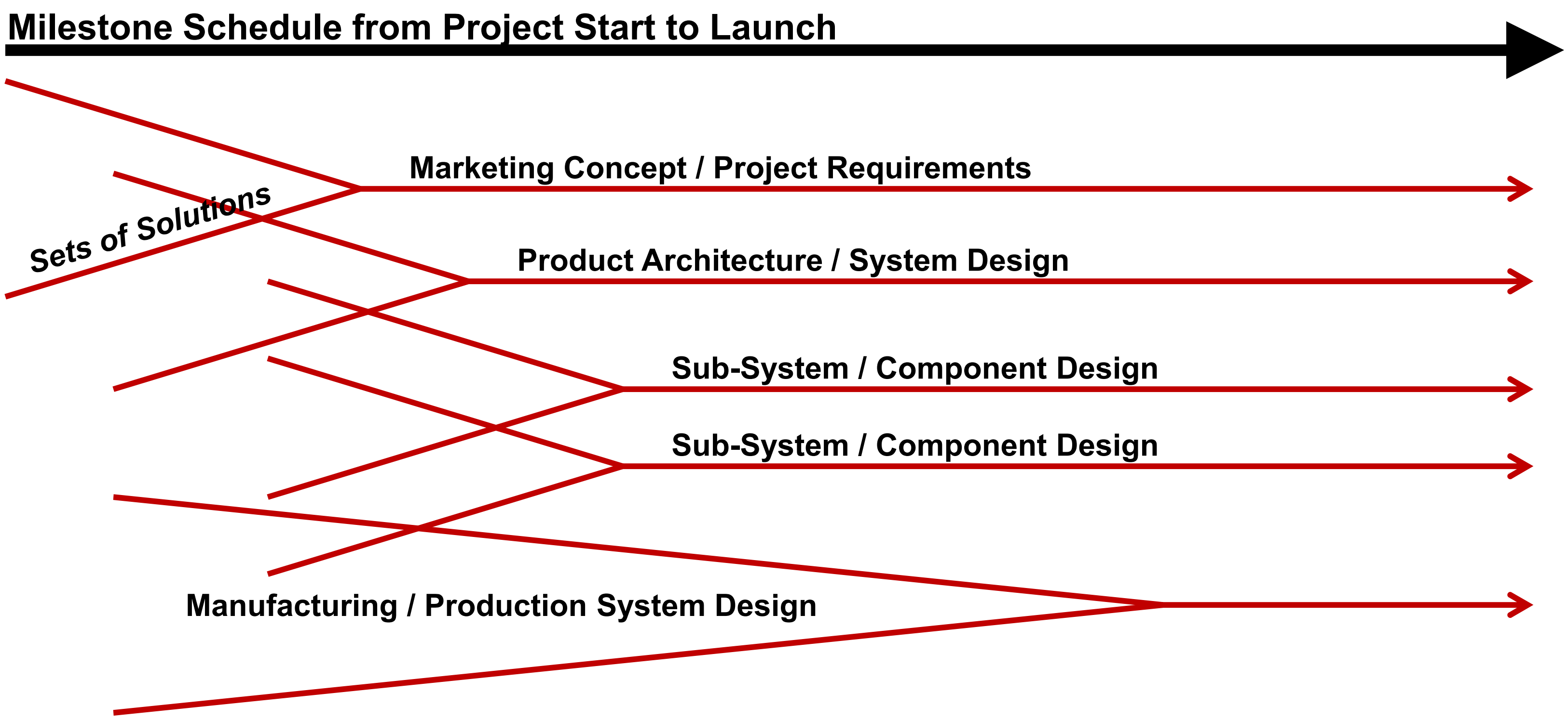
Set-Based Concurrent Engineering



Ready, Set, Dominate – Implement Toyota's Set-Based Learning for Product Development; Michael Kennedy, Kent Harmon, Ed Minnock; 2008

Set-Based Concurrent Engineering

- **Testing solution sets then converging by the milestone deadline for each subsystem**



Adapted from: ***The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster*****; Ward, Liker, Cristiano, Sobek; MIT Sloan Management Review, April 15, 1995; Figure 3**

Set-Based Concurrent Engineering

- **Why SBCE works**
  - **A simple example. Picking a meeting time.**

Normal Meeting Approach	SBCE Meeting Approach
Pick a time, invite attendees	Collect all available meeting times of participants
One person can't make that time, mutually agree to new time	Intersect the *set* of all meeting times to pick a time when everyone is available
Another person can't make new time, reiterate process	
Alternatively, mandate time and require attendees to change schedules or have a meeting to schedule a meeting	

***The Second Toyota Paradox: How Delaying Decisions Can Make Better Cars Faster*;**
Ward, Liker, Cristiano, Sobek; MIT Sloan Management Review, April 15, 1995

A Process for SBCE

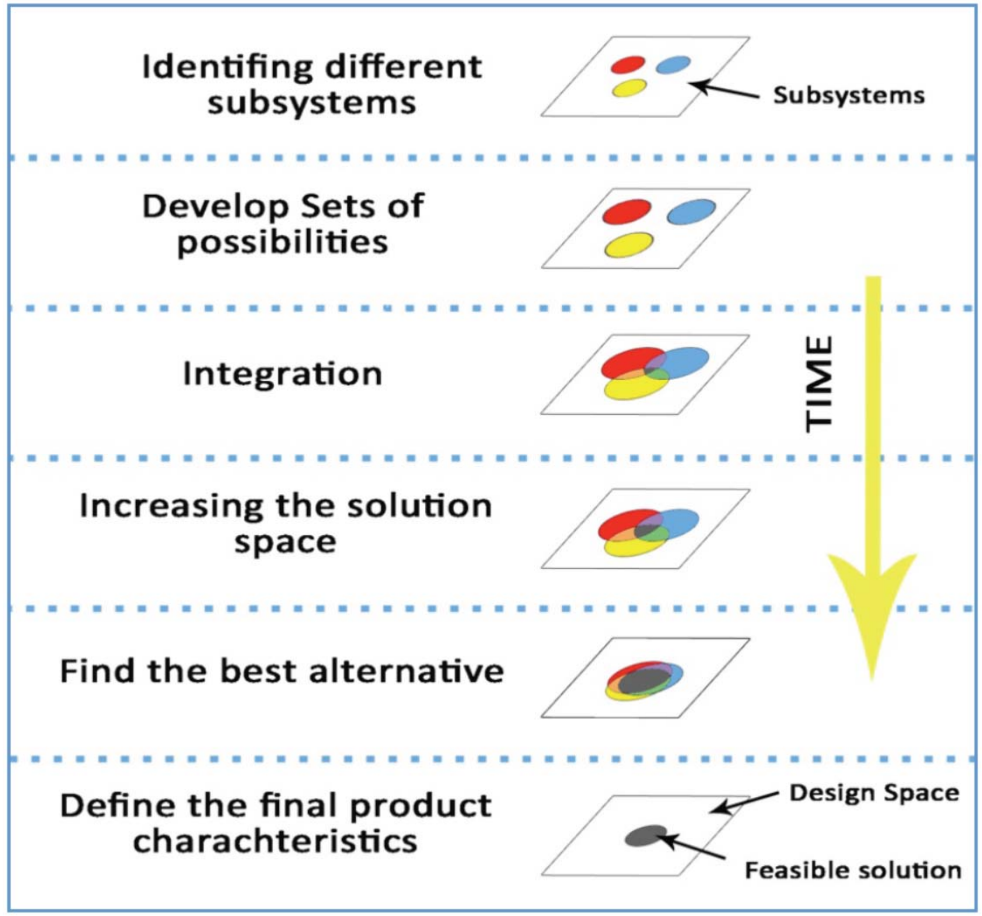
1. Define System

2. Define Sets

3. Concurrent Engineering

4. Converge Slowly

5. Define Solution



Assessing Principles of SBCE Using a Design Game, Thesis of Francesc Carbó Roma, Chalmers Institute of Technology, Gothenburg Sweden, Figure 2

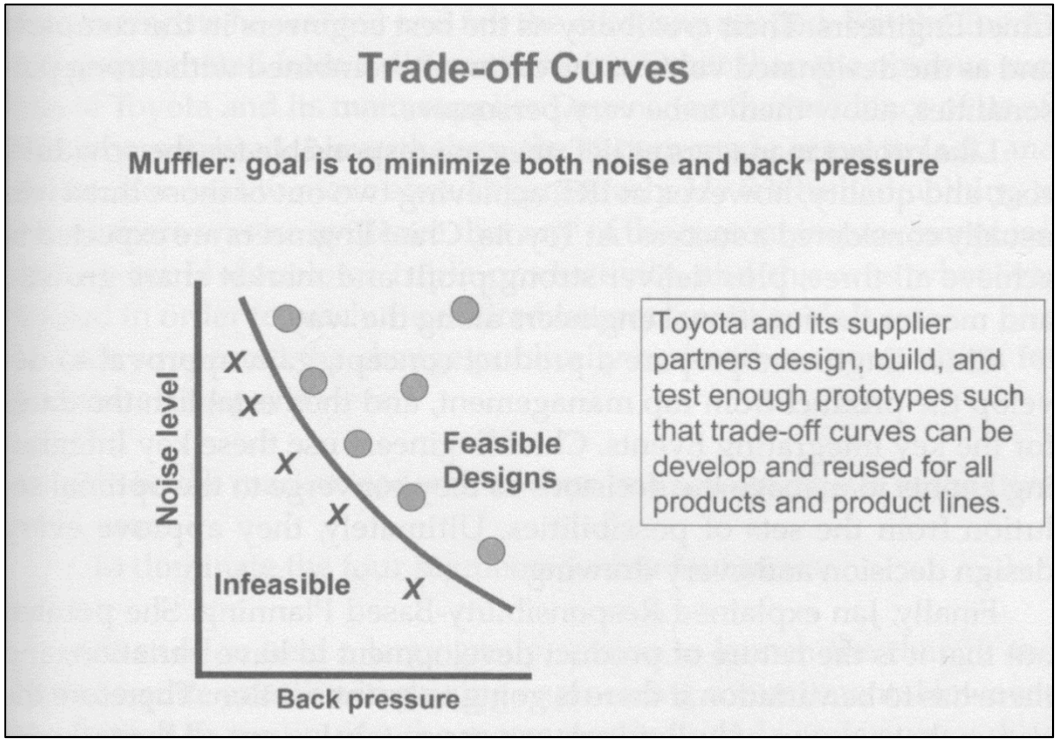
Summary Principles of SBCE

1. **Evaluate Multiple Alternatives**
   - A single design concept is highly risky
   - Invest heavily in prototyping
2. **Tradeoff Curves**
   - Maintain Tradeoff Curves that define relationships of prototype tests
3. **Solution Convergence**
   - Prototype, Test, Learn, Combine, Narrow
4. **Redundancy**
   - Have a backup design for subsystems, typically an existing design

Source: Product Development for the Lean Enterprise, Michael Kennedy, 2003

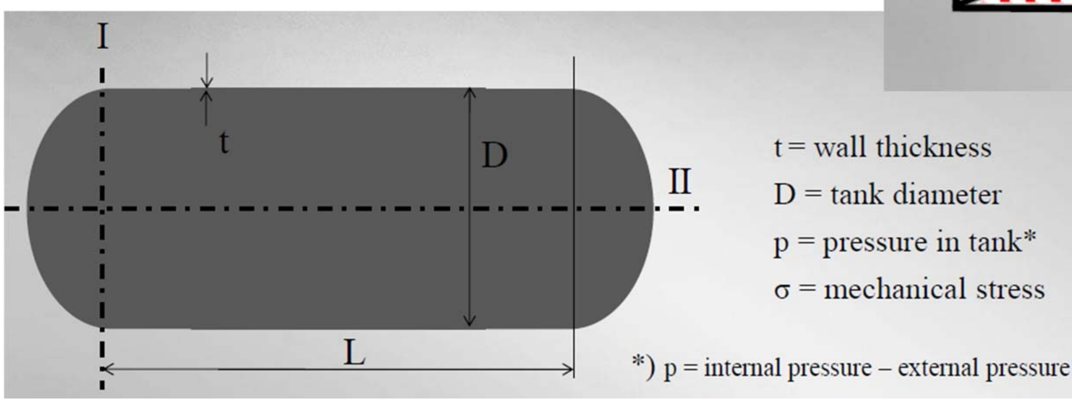
What is a Trade-off Curve?

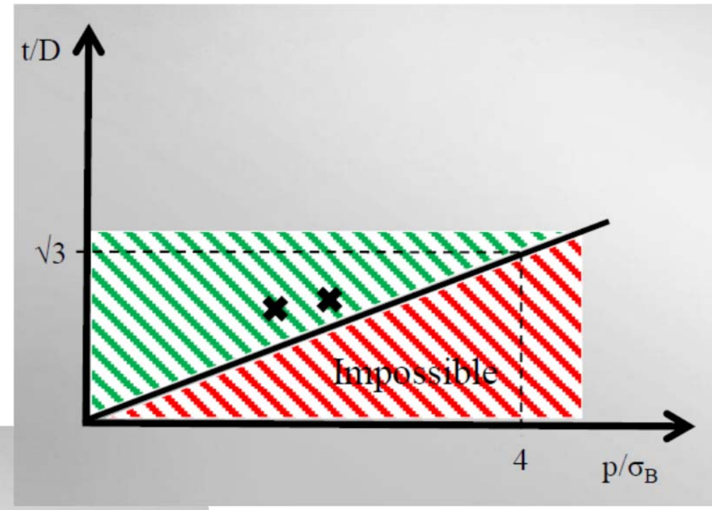
- **Generalizing knowledge for reuse in current and future projects**



Ready, Set, Dominate – Implement Toyota's Set-Based Learning for Product Development; Michael Kennedy, Kent Harmon, Ed Minnock; 2008

Trade-off Curve Example





If the mechanical stress in the tank equals the fracture stress σB, we can derive the non-dimensional relationship t/D = (√3/4)·p/σB

Trade-off Curves and Feasible Regions; Göran Gustafsson, M.Sc., Ph.D.; Chalmers University of Technology, Gothenburg, Sweden

What is a Knowledge Brief?

- **Knowledge Brief**
  - **a.k.a. “K-Brief”**
  - **A highly summarized documentation of learning from prototyping and other experimentation**
  - **Used to communicate solutions sets during SBCE**
  - **Typically only A3 size (11x17”)**
  - **An adaptation of the “A3” Problem Solving tool**

Knowledge Brief Example

Elements:
- Parameters
- Guidelines
- Calculations
- Trade-off Curves
- Examples

K-Brief: EV Powertrain – Motor Subsystem

Design Parameters

- Torque of a motor is a function of power input and Speed (rpm) output
- Torque and Speed are inversely proportional and assumed to be linear (actual measurement is very close).
- Torque Current and Output Power can be calculated given Maximum (Stall) Torque and Maximum Motor Speed
- Input Power can be estimated given No Load amperage and Torque Current
- Efficiency of motor output is simply Output Power divided by Input Power resulting in a percentage

Design Guidelines

- Given the design parameters provided above, a Torque-Speed curve can be prepared to give the designer a range of operating conditions
- Maximum Power is achieved at half of the motor speed
- However, maximum efficiency is achieved typically between 70-90% of motor maximum speed
- Therefore, maximum power is achieved near 50% motor speed. However, efficient operation will be at higher Speed with lower Torque.

Calculations

$$T = P/(2\pi/60\ n)$$

Where:
T = torque in Nm
P = power in watts
2π = radian revolutions per second
60 = conversion of seconds to minutes
n = motor revolutions per minute

$$Proportionality\ Constant = k_m = \frac{Max\ Speed}{Stall\ Torque} = rpm/Nm$$

$$Current = A = \frac{Torque}{k_m} = Amps$$

$$Power = Watts = Torque \times Speed = Torque \times rpm \times \frac{2\pi}{60} = Watts \times \frac{1}{1000} = kW$$

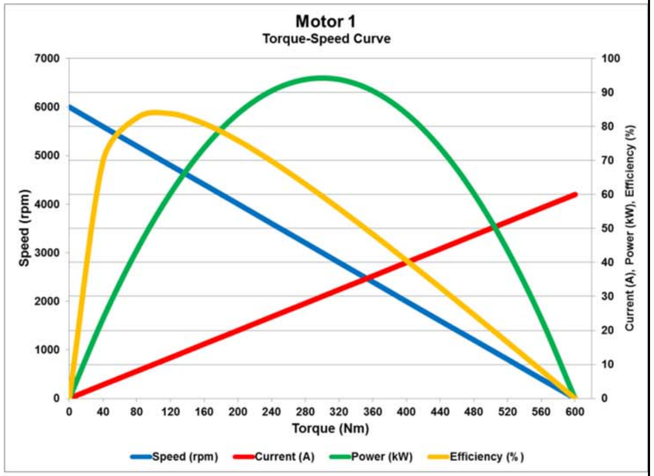
$$Input\ Power = Watts = Volts \times (Torque\ Amps + No\ Load\ Amps) = Watts \times \frac{1}{1000} = kW$$

Where: No Load Amps is estimated at 5% of maximum Amps (a function of motor design)

$$Efficiency = \frac{Power}{Input\ Power} = \%$$

K-Brief: EV Powertrain – Motor Subsystem

Trade-off Curves



Examples

Source of Torque-Speed Curve Formulas and Instructions:
http://www.micromo.com/technical-library/dc-motor-tutorials/motor-calculations

Navarre, L., Kettering University, BUSN 304, *Intrapreneurship and Innovation Development*, SBCE Exercise

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Time to Exercise

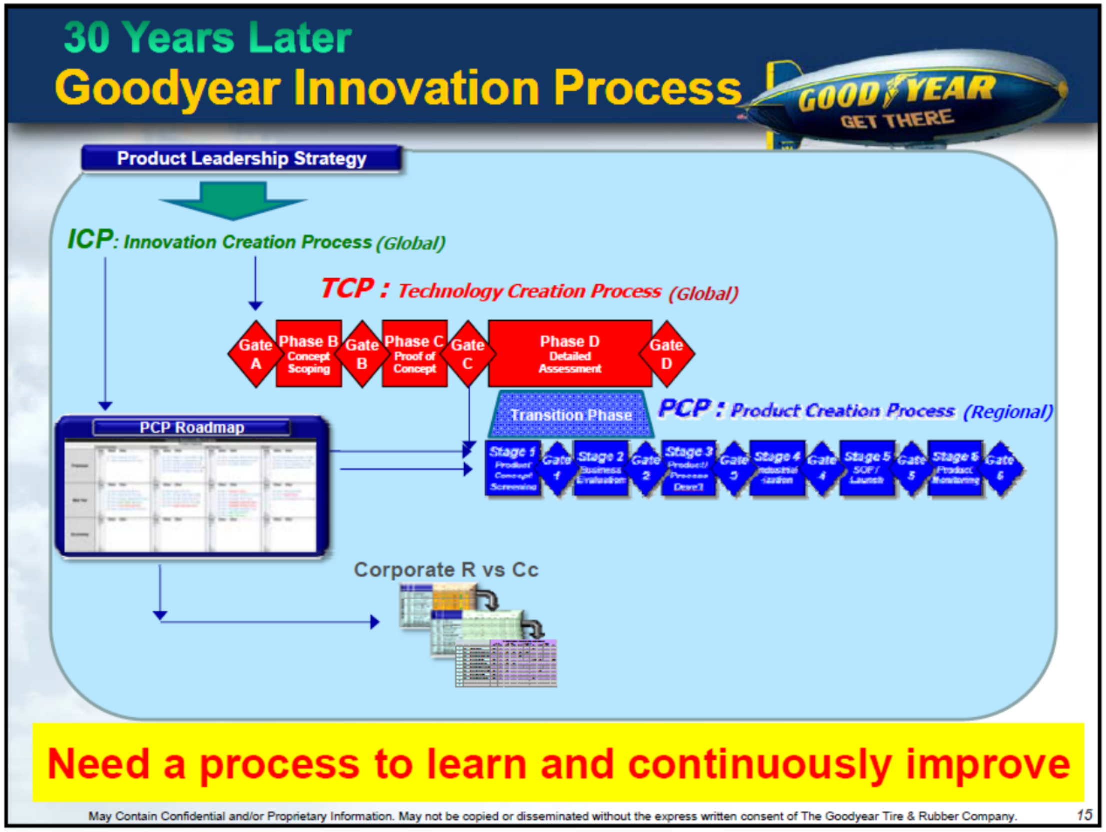
Exemplar Practitioners of LPPD

- **Since the 1990's realization of LPPD at Toyota, the following companies have adopted the approach:**

Company	Industry	Company	Industry
Toyota	Auto OEM	GE Appliance	Appliances
Denso	Auto Supplier	Teledyne Bathos	Instruments
Delphi	Auto Supplier	Fisher & Paykel	Appliances
Ford	Auto OEM	Goodyear	Tires
Novo Nordisk	Medical Devices	Pratt & Whitney	Aircraft Engines
Steelcase	Furniture	Harley-Davison	Motorcycles

Changing Traditional Processes to Lean

Goodyear transformed its NPD process to LPPD



Copyright 2014, Goodyear Tire Corporation

Presented by Majerus at Lean Product and Process Development Exchange, 9/23/2014

Leadership by the Chief Engineer

Ford consolidated PD leadership to the CE

The Results

First 2015 Mustang rolls of the line on August 28, 2014

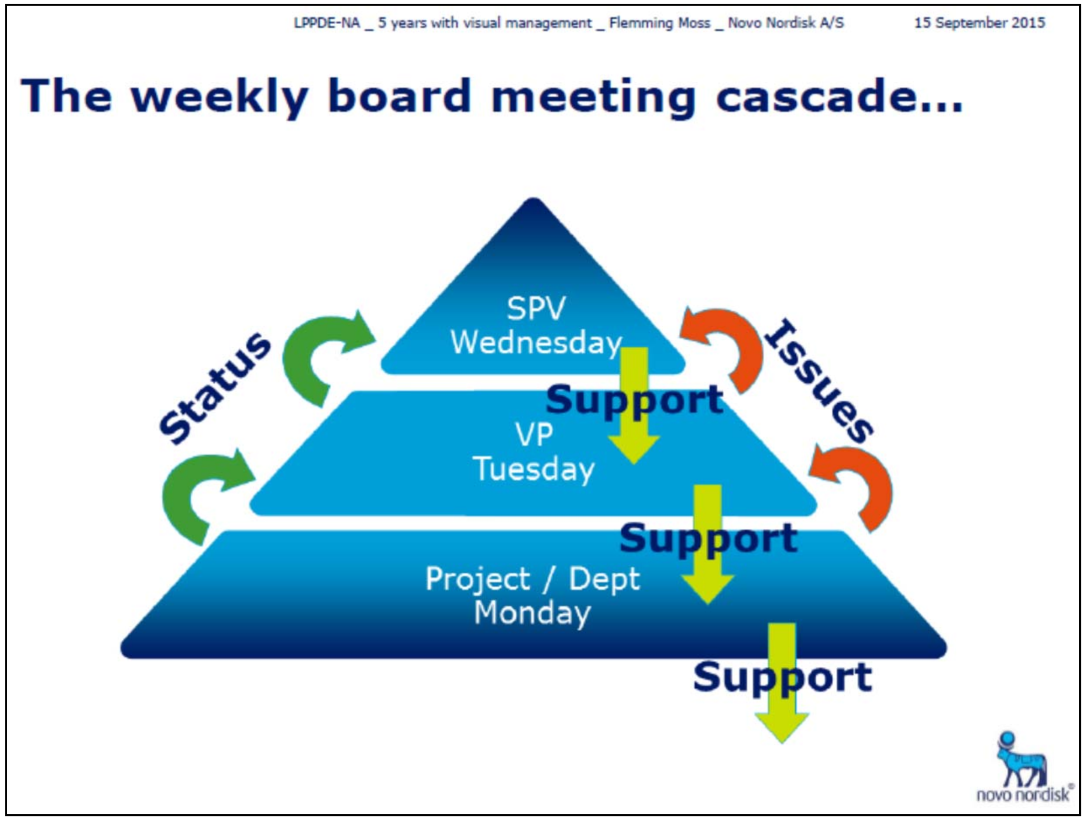
Copyright 2014, Ford Motor Company

Presented by Pericak, Mustang CE, at Lean Product and Process Development Exchange, 9/23/2014

Using Lean Tools in Development

Novo Nordisk uses Visual Management for Organizational Alignment and Senior Management Support

- Escalate Issues
- Senior Management Involvement and Support
- Senior Management also using VM

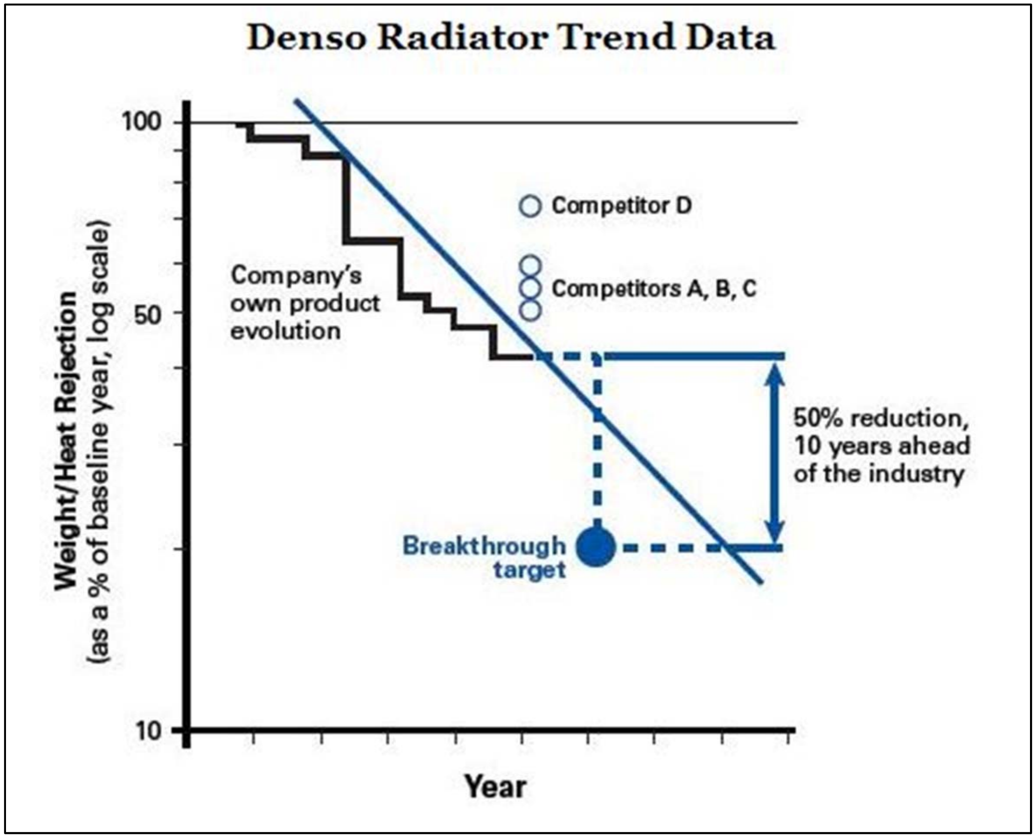


Moss, Fleming; Novo Nordisk; *5 Years with Visual Management,* LPPDE 2015 Conference

Testing, Learning, Knowledge Reuse

Denso radiator performance vs. competitors and goals

- Note the universal metric "weight / heat rejection" and log scale



Ward, Sobeck; *Lean Product and Process Development*, Lean Enterprise Institute, 2014

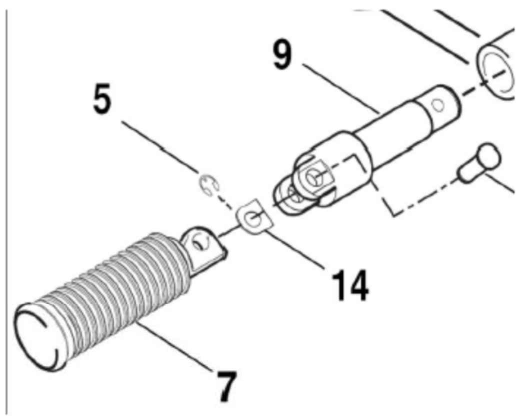
Testing, Learning, Knowledge Reuse

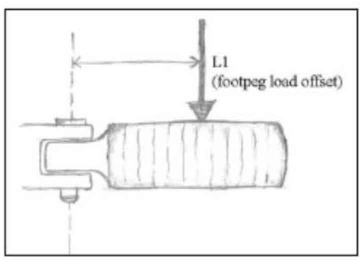
Harley-Davidson uses SBCE

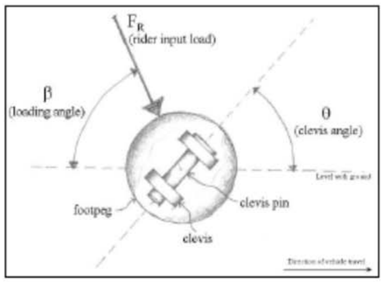
Lesson Learned

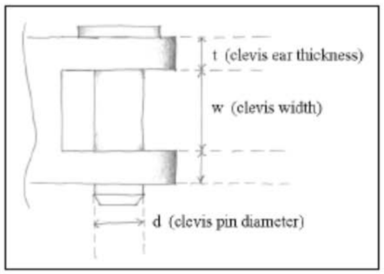
Process Steps:

1. Define the variables
2. Show how the variable relate
3. Make hypothesis
4. Develop tradeoff curves







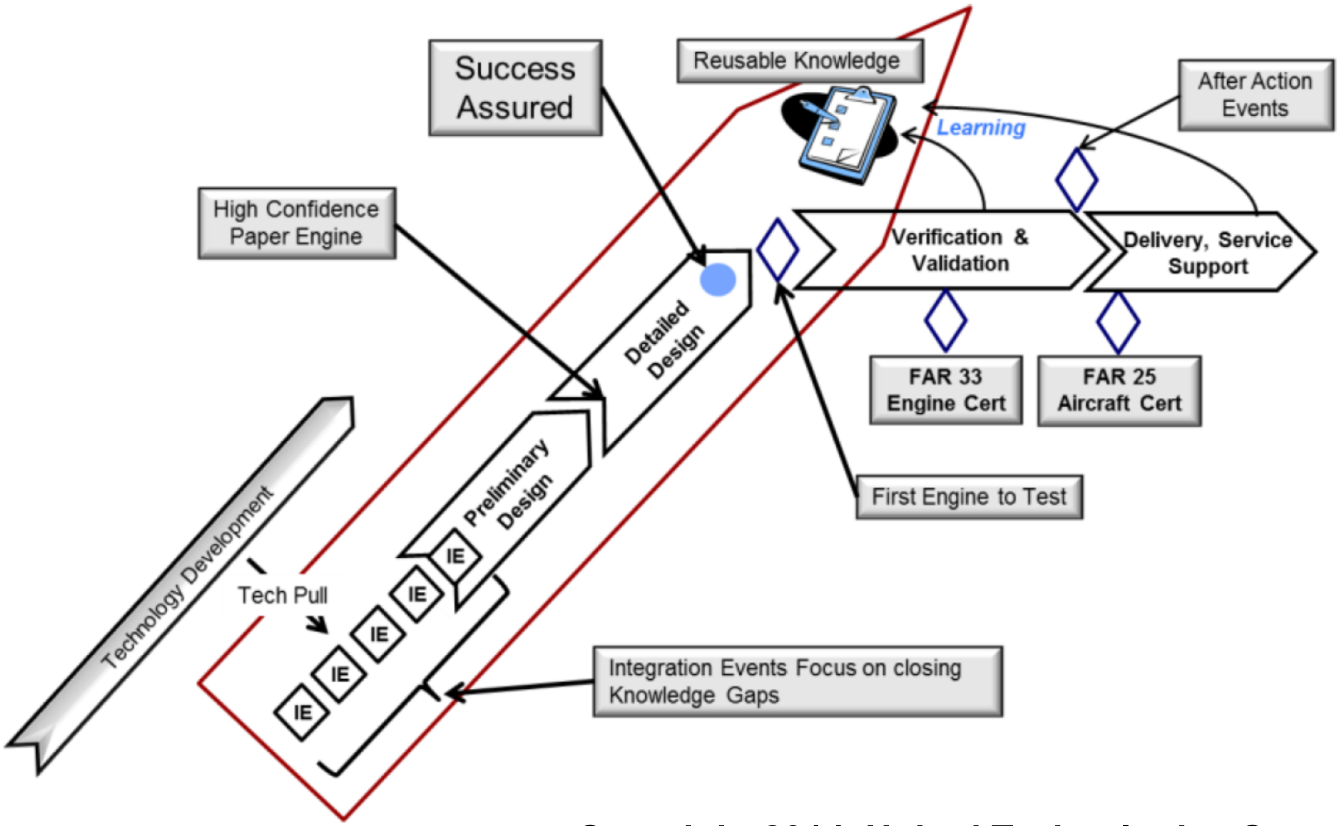


Copyright 2015, Harley-Davidson Motorcycles

Presented by Wilcox at Lean Product and Process Development Exchange, 9/15/2015

A Learning Organization

- **Pratt & Whitney Aircraft Engines**



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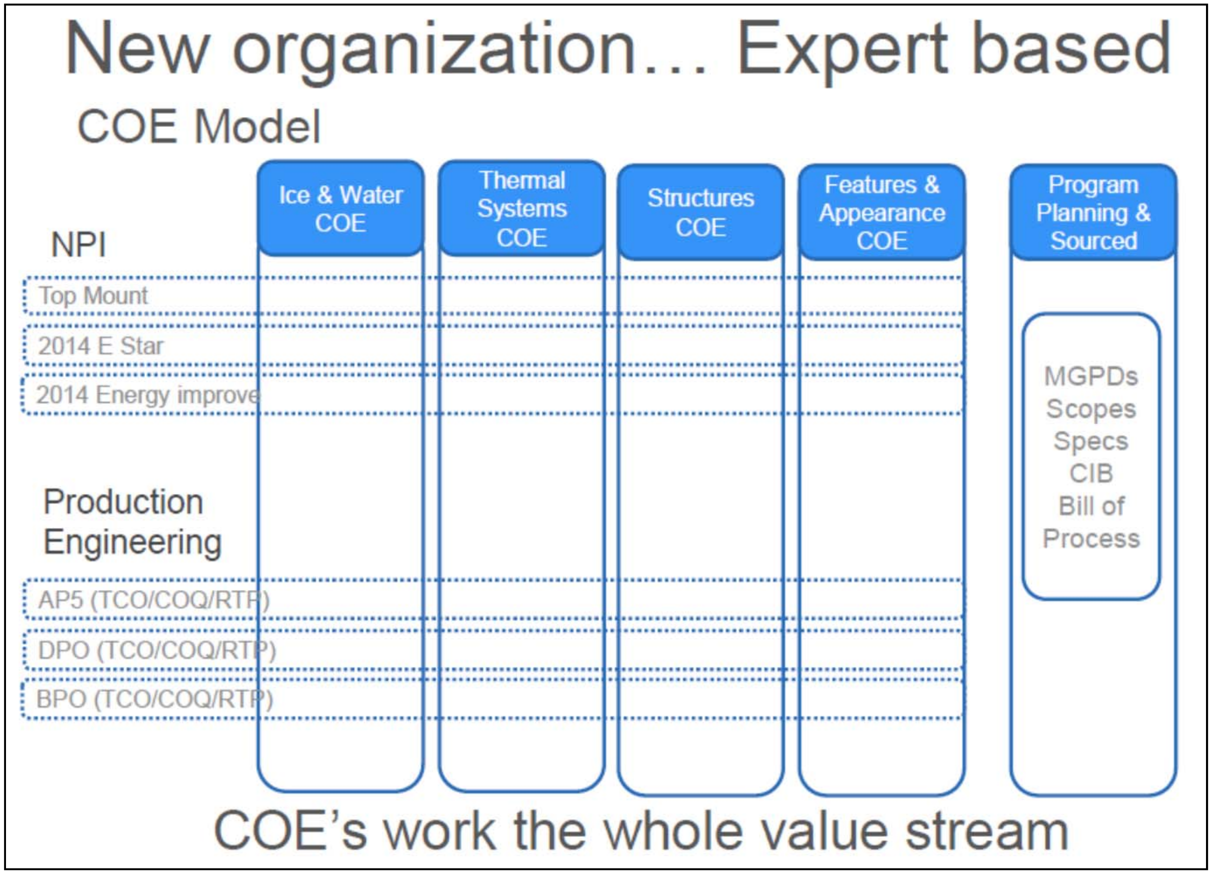
A Lean PD Transformation

GE Appliance reorganized to Centers of Excellence



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Comments on LPD by Jim Womack

"You have hardly got started!"

Jim Womack, PhD, Professor at MIT
Co-author of the Machine that Changed the World and Lean Thinking
Founder of Lean Enterprise Institute
Presenting at Lean Product and Process Development Exchange, 9/23/2014

Womack's Insights:

- LPD is relatively "new", few practitioners are doing it
- Clearly, the leaders in development are doing it
- LPD is not nearly as visible as Lean Manufacturing, and appears much more difficult
- Reflection: have the courage to experiment with LPD

Thank You !

Contact:

Larry Navarre, lnavarre@kettering.edu